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THE BRINE SHRIMP
ARTEMIA

Guido PERSOONE, Patrick SORGELOOS,
Oswald ROELS and Edmonde JASPERS

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State University of Ghent
J. Plateaustraat 22
B-9000 Ghent, Belgium

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Technological aspects of the batch culturing of *Artemia* in high densities

Etienne Bossuyt[1,3] *and Patrick Sorgeloos*[2,4]

[1] *IZWO, Institute for Marine Scientific Research*
Prinses Elisabethlaan 69, B-8401 Bredene, Belgium

[2] *Artemia Reference Center, State University of Ghent*
J. Plateaustraat 22, B-9000 Ghent, Belgium

Abstract

Contrary to the rearing of brine shrimp at laboratory scale which is current practice and well described in many papers, specific information on the high-density culturing of this species is scanty.

This paper briefly reviews the different culturing methods precognized so far and discusses the advantages of batch culture in air-water-lift raceways ; the latter technology has been optimized during the last 4 years at the Artemia Reference Center and permits a current production of 2 kg biomass/m^3 in 2 weeks culturing at 25 °C.

A detailed description is given of :

1. construction of the raceways : tank design and characteristics and selection of materials ; construction, positioning and operation of the air-water-lifts ;
2. techniques for water heating and heat insulation ;
3. equipment and methods for (semi-)automatic food distribution ;
4. separation-techniques for continuous removal of faecal pellets from the culturing medium ;
5. culture procedures.

Introduction

During the last decade several techniques have been described for the high-density culturing of brine shrimp in batch systems.

Dohse (1971) is working with a so-called "Artemium" consisting of shallow basins of 100 l contents which are piled up. In each plastic basin, a rotating blade continuously stirs the culture medium and accumulates uneaten food and faecal pellets in a central depression from where they can be siphoned off. The culture medium is not changed during growth of the larvae. The food consists of a commercial mixture of dried algae, yeast, and alfalfa and is distributed manually once a day.

Sorgeloos (1973) proposed a culture system of 30 l transparent plastic columns installed in parallel in metal racks. The working principles, which have also been adopted by Dohse (1973) for the improvement of his "Artemium", are as follows :

[3] Present address : Artemia Reference Center, State University of Ghent, J. Plateaustraat 22, B-9000 Ghent, Belgium.

[4] "Bevoegdverklaard Navorser" at the Belgian National Foundation for Scientific Research (NFWO).

a. intermittent aeration of the medium (10 sec every half hour) which assures a good oxygenation and does not harm the animals ;
b. automatic food distribution once an hour which greatly improves the feeding efficiency of the brine shrimp. As far as the latter factor is concerned it is indeed known that "... the food remains in the gut progressively longer, as there is less pressure on it from the incoming food to move through the gut" (Reeve, 1963) ; Ideally feeding should even be "dropwise" as advised by Provasoli and D'Agostino (1969).

Although excellent growth and survival are obtained with this "column" culturing system its application at a large scale is not economically feasible by some inherent drawbacks such as :
- renewal of the culturing medium every 2nd or 3th day involving extra costs for heating and manual labor ;
- the necessity of using expensive air compressors to aerate "high" water columns (1.5 to 2 m) instead of axial blowers which now are mostly used in aquaculture hatcheries.

The need for repeated water renewals during larval growth was overcome by Person-Le Ruyet (1976) by the gradual decrease of the density of animals from 20 to 1/ml through gradual increase of the volume of the culture. This technology as well as the culturing method in shallow containers proposed by Jahnig (1977), are unfortunately very labor intensive and hard to automatize.

The ideal *Artemia* culturing technique suitable for large scale application implies, in our opinion, the following prerequisites :
a. good oxygenation of the medium to allow culturing at high density (thousands of animals per liter) ;
b. continuous circulation of the medium to maximize food availability to the brine shrimp which are swimming continuously ;
c. shallow water depth (not exceeding 1 m) to allow the use of inexpensive axial blowers ;
d. possibility for automatization, which implies that water-renewals should be restricted as much as possible ;
e. possibility of upscaling which should neither involve major changes in tank design nor in culturing principles.

Of the various techniques which we have tested out for growing *Artemia* larvae in batch culture from nauplius to adult, the air-water-lift (AWL) operated raceway, originally described by Mock *et al.* (1973, 1977) to culture benthonic postlarval *Penaeus*, proved to be the most suitable (Sorgeloos *et al.*, 1977ab). The construction and operation of the culturing tank is indeed simple and very high production results can be obtained.

An air-water-lift operated raceway (AWL-raceway) basically consists of a rectangular tank provided with a central partitioning and air-water-lifts (AWL's). By the specific configuration of the tank and the identical positioning of the AWL's, a screwlike, unidirectional circulation of the culturing medium is achieved, which results in the following effects :
- aeration of the medium is continuous ;
- circulation of the whole medium is almost homogeneous ;
- nearly all particulate matter is kept in suspension ;
- feed added at one place is distributed all over the tank within a few minutes ;

– the system can be scaled up at will, taking in consideration, however, that the height-width ratio of the culturing tank is critical.

It is clear that, prior to consider any adaptation of the original AWL-raceway technique for culturing brine shrimp, it was necessary to find out if the animals (the larvae as well as the adults) are not injured by their intermittent passage through the AWL-pipes. Preliminary tests carried out in small 60 l raceways revealed that high survival and acceptable growth rates could be obtained (Sorgeloos, 1975 ; Bossuyt, 1976).

During the past 4 years we have grown millions of brine shrimp in various types of AWL-raceways, the contents of which ranged from a minimum of 10 l up to a maximum of 5 m^3. In this paper we have tried to summarize the state of the art of our present knowledge on construction and operation of AWL-raceways for batch culturing of brine shrimp.

Construction of the AWL-raceway

Tank design and characteristics

An *Artemia* raceway essentially consists of a rectangular tank with a central partitioning. The corners of the tank may be curved, although this is not absolutely necessary (Fig. 1). In order to assure an optimal water circulation the central partitioning should not be closer to the wall of the small side than 1 to 2/3 of the channel width (W in Fig. 1) and not further than once this width. The partitioning should also be kept 2 to 5 cm off the bottom of the tank either by suspending it from two or more woorden bars resting on the sidewalls of the raceway or by keeping it in its central position on top of two small blocs on the bottom with the aid of rubber bands (*e.g.* cut from an inner tube of a bike) stretched over the top of the partitioning. The most important parameter for the configuration of the tank is the height/width ratio which, in our opinion, should be kept close to 1.

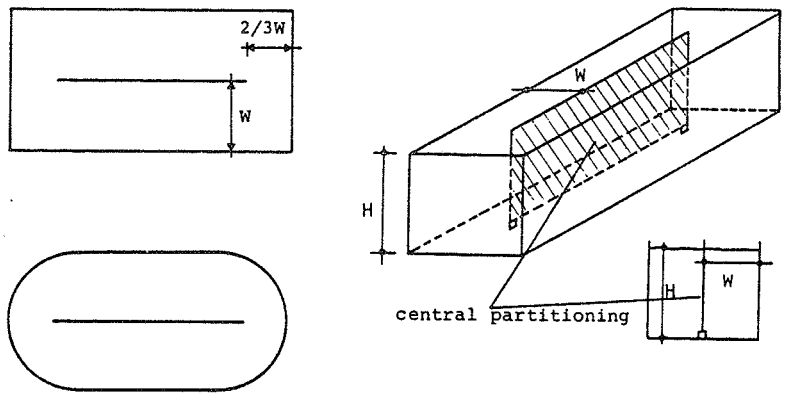

Fig. 1. Top and side views of *Artemia*-raceways illustrating the positioning of the central partitioning (height H and width W of water column).

For optimal water circulation, using axial blowers, the water depth should not exceed 1 m. Deeper tanks indeed require the use of more expensive air-compressors, whereby the resulting widening of the tank (to keep the height/width ratio close to 1) decreases the efficiency of water circulation which can be obtained with one row of AWL's.

Various materials can be used to construct raceway tanks, *e.g.* concrete, marine plywood, fiberglass. We found a very convenient solution for the basic structure by using aluminum plates supported at the outside by angle-irons. The latter are either fixed with bolts into a concrete floor (Fig. 2) or, when constructed on soft bottoms, interconnected at the bottom by an iron frame and by a steelcable at the top (Fig. 3). Several techniques can be considered to make the tanks watertight such as plastic liner or glass fiber coating ; we mostly use PVC-liners, 0.5 to 0.85 mm thick.

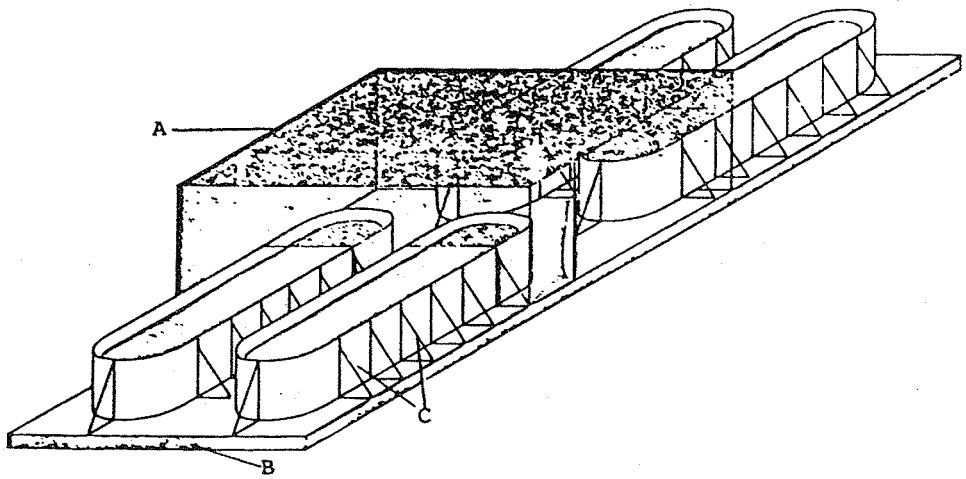

FIG. 2. Scheme of pilot plant of four 5 m³ raceways for batch culturing of *Artemia* constructed at the Belgian coast. (A) central sheltered workplace, (B) concrete flour, (C) supporting angle irons.

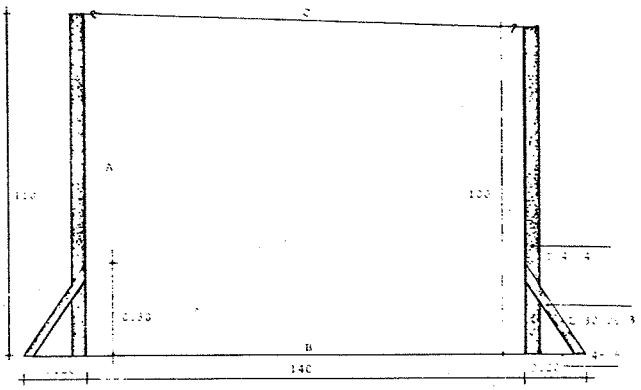

FIG. 3. Alternative frame construction for raceway on soft bottom using angle-irons (A), iron band (B), and steel cable (C), (all lengths in cm).

CONSTRUCTION AND POSITIONING OF THE AWL'S

The easiest way to construct an AWL is to use sanitary PVC-pipes and elbows. The lower part of the tube is cut at an angle of 45° and stands on the bottom of the raceway (Fig. 4). In case elbows are not available, it suffices to cut the upper part of the tube at 45° and seal the two pieces as shown in Fig. 4B.

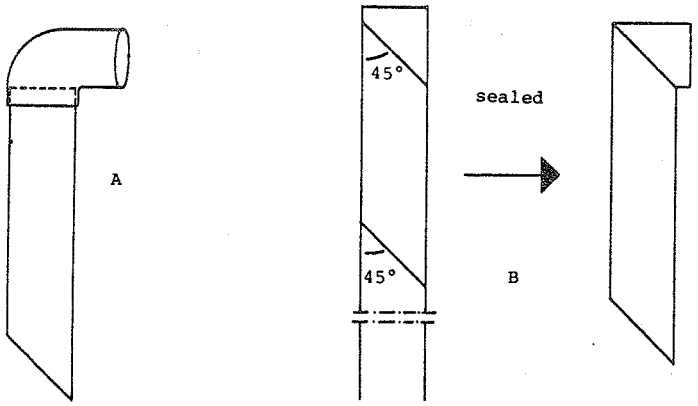

FIG. 4. Air-water-lift (A) assembled with an elbow piece or (B) entirely made of a piece of PVC-tubing.

Depending on the materials available, various systems can be considered to attach the AWL's to the central partitioning to keep them in a well defined position for an optimal watercirculation in the raceway (Fig. 5). For this purpose the elbow outflows should make an angle of 30 to 45° with the central partitioning. Although the oxygenation of the culturing medium is maximal when the AWL's outflow extends a few centimeters above the water surface [according to Spotte (1970) the splash-down of the water back into the tank assures a better aeration than the effect of the air-bubbles within the pipe], we always keep the outflows of the AWL's half submerged to prevent formation of tiny air bubbles. We indeed experienced that ingestion of small air bubbles by the brine shrimp or their trapping between the thoracopods makes the animals float and leads to mortality. For the same reason we never put air stones in the AWL's, although it is well known that these can greatly aid to optimize the oxygenation effect. Air stones furthermore cause foam formation which again can result in mortality because brine shrimp trapped in the foam cannot get back in the water.

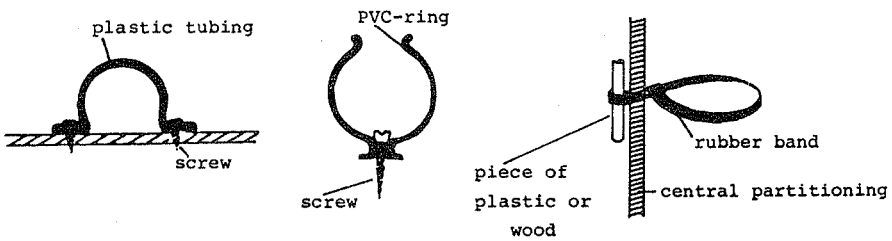

FIG. 5. Three different systems for attaching AWL-pipes to the central partitioning of a raceway.

With regard to the number of AWL's per tank, optimal circulation and aeration is obtained with pipes installed at 25 to 40 cm intervals. In order to assure the maximal water-lift-effect, it is clear that the diameter of the AWL's should be related to the water depth. Based on our experience we can advise the following relationship :

Water level (cm)	Inner diameter (mm)
20	25
40	40
75	50
100	60

The configuration and dimensions of three raceway systems which over the years have given satisfactory results in *Artemia* culturing are given in Fig. 6.

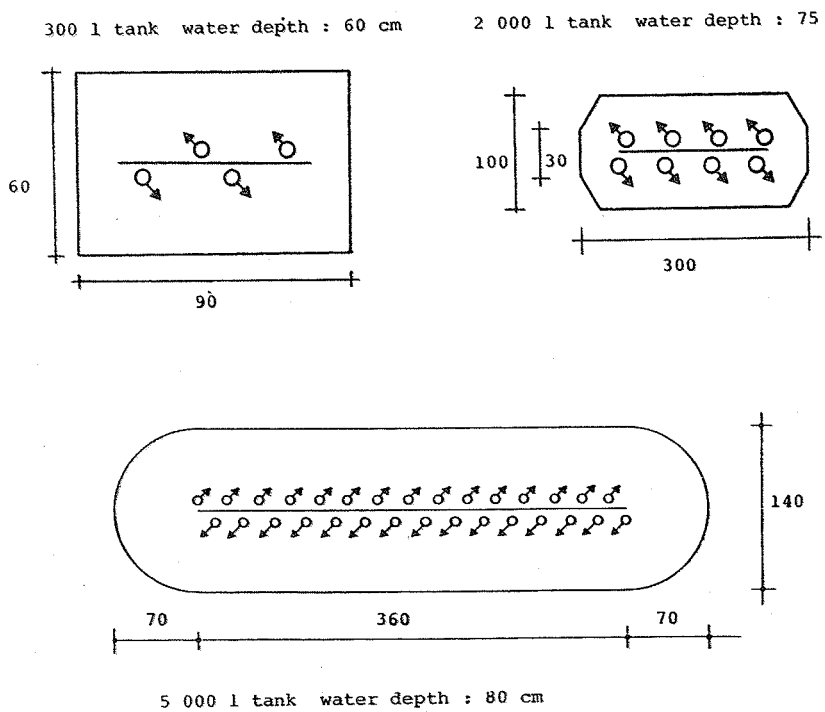

FIG. 6. Top views and dimensions of three raceway-systems for *Artemia* culturing (length in cm).

AIR-DISTRIBUTION INTO THE AWL'S (Fig. 7)

The aeration-line (*e.g.* small polyethylene tubing, 6 mm in diameter) can be mounted in the AWL through a hole on top of the PVC elbow. By making this opening slightly smaller than

the outer diameter of the tubing, the aeration-line can be risen or lowered at will and its thight fitting in the elbow prevents any undesired displacement. The aeration lines should extend as deep as possible in the AWL's to assure the best water-lift effect.

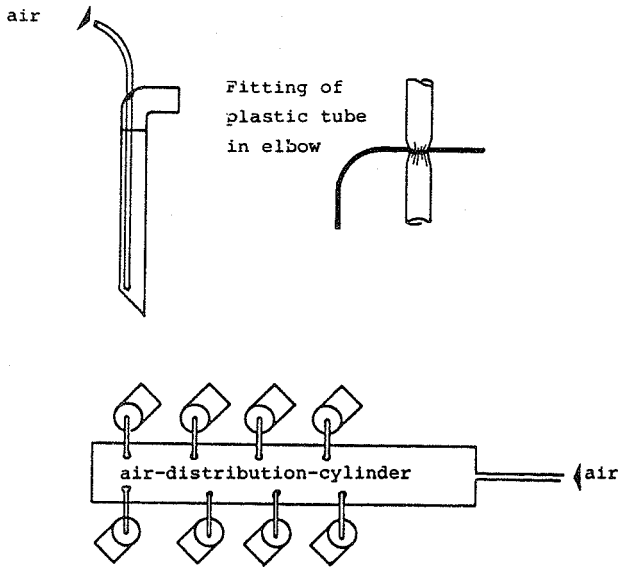

FIG. 7. Details on the installation of airlines in AWL-raceways.

Instead of using expensive valves for each individual aeration line, the different tubes are connected to a central air-distribution cylinder provided with holes wich are smaller than the outer diameter of the plastic air tubes to assure an airtight fitting of the tubes. An identical and constant aeration is obtained by adjusting all air tubes to the same hydrostatic depth in the AWL's. At water depths of 50 cm and more, the adjustment of the air-flowrate in individual AWL's can be greatly facilitated by mounting a small piece of perforated PVC-tubing on the air-outlet (Fig. 8).

The AWL-characteristics of a few raceways operated successfully for *Artemia* culturing are summarized in Table I. Further research is in progress to optimize dimensions and operation conditions.

TABLE I

AWL-characteristics of a few raceways operated successfully for *Artemia* culturing

Water level (cm)	Inner diameter AWL (mm)	Volume of air per AWL (l/min)	Volume of water displaced per AWL (l/min)
20	25	2.7	4.0
40	40	6.6	12.5
75	50	14.0	38.0

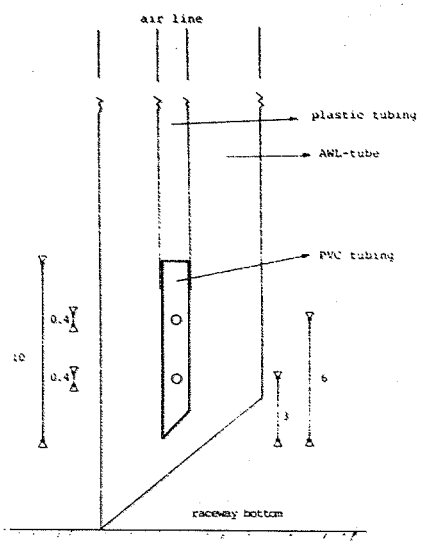

FIG. 8. Detail of bottom part of AWL used in raceways with water depths of 50 cm and more (dimensions in cm).

SELECTION OF MATERIALS

It is clear that all materials which are in direct contact with the culturing medium have to be non-toxic for *Artemia*. Materials withheld so far are : PVC-pipes and tubes ; concrete or wood (marine plywood) coated with epoxy-paint or fiberglass or lined with PVC, or polyethylene-sheet.

HEATING OF THE CULTURE MEDIUM

The optimal culture temperature for brine shrimp is situated in the range 25-30 °C. To heat and keep the culturing medium at such high water temperatures, heaters and thermostats (made of stainless steel, glass or otherwise incorporated in non-corrosive materials) can be directly immersed in the water. Various indirect heat exchangers which are used in mariculture can also be used (Huguenin, 1976).

The first system we worked with, consisted of a copper coil tubing covered by an aluminum plate 1 mm thick and located underneath the PVC-liner on the bottom of the raceway (for more details see Fig. 9 and Sorgeloos *et al.*, 1977b). Freshwater, heated in a separate tank at 50 °C was circulated through this heat exchanger and temperature was controlled by a thermostat immersed in the culture medium.

More recently we experienced that plate radiators, commonly used in domestic central heating are very useful for raceway culturing. Coated with an epoxy-paint they function at the same time as heat-exchanger and central partitioning to which the AWL's can be fixed.

Heat losses can be minimized by proper insulation of the culture tank, *e.g.* with styrofoam or polyurethane. Water evaporation, (which is the major cause of heat losses) can be greatly

reduced by placing an insulated cover (also provided with styrofoam) on top of the raceway ; the non-transparent cover is furthermore beneficial for the food conversion since brine shrimp grow faster in darkness than in light (Sorgeloos, 1972).

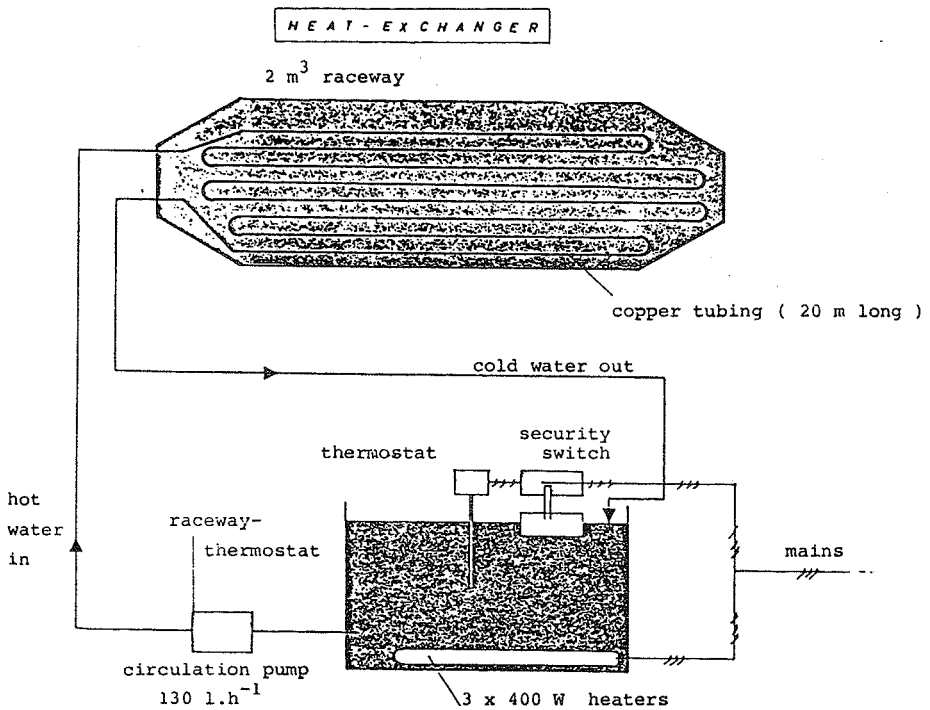

FIG. 9. Schematic diagram of a coppercoil heat exchanger used in a 2 m³ AWL-raceway.

Feeding conditions

SELECTION OF FOOD

From literature it appears that a wide range of live and inert feeds can be successfully used to culture the brine shrimp (review by Sorgeloos and Persoone, 1975). Since *Artemia* is a non-selective, obligate, particle feeder (Barker-Jörgensen, 1966 ; Provasoli and D'Agostino, 1969) the critical factors in selecting a suitable diet for brine shrimp are its particle size which should be less than 50 μm (Dobbeleir *et al.*, 1980), digestibility, nutritional value (to be tested experimentally) and solubility in the culturing medium (which should be minimal). Soluble products indeed, are not taken up by *Artemia* and, since they will be decomposed by bacteria in the culture medium they contribute to a deterioration of the water quality by the gradual build up of toxic substances such as ammonia (Hanaoka, 1973, 1977).

Different waste products of major agricultural crops or from bio-industries have been found to be a very suitable food source for *Artemia*, *e.g.* rice bran, soybean meal and whey

powder (Dobbeleir *et al.*, 1980). Most experience in raceway culturing was gained so far with rice bran (Sorgeloos *et al.*, 1980).

Food distribution

Since *Artemia* is a continuous filter-feeder the fastest growth and the most efficient food conversion is obtained at constant food densities (Reeve, 1963 ; Provasoli and D'Agostino, 1969). For batch culturing this means that food has to be distributed as frequently as possible either manually or preferably automatically.

The optimal quantity of food to be distributed per feeding is function of many variables, such as larval density, instar-stage, water temperature, *etc.* and makes dosing a very difficult task. We found a practical solution in using the turbidity of the medium as a parameter for the food dose. A rough estimation of turbidity can be made with a self-made turbidistick, which is in fact a type of Secchi-disc-meter (Fig. 10). The practical procedure is very simple : the turbidistick is submerged and lowered until the bottom plate is just still visible ; rice bran-suspension is then added till the turbidity, measured with the stick, is approximately 15-20 cm.

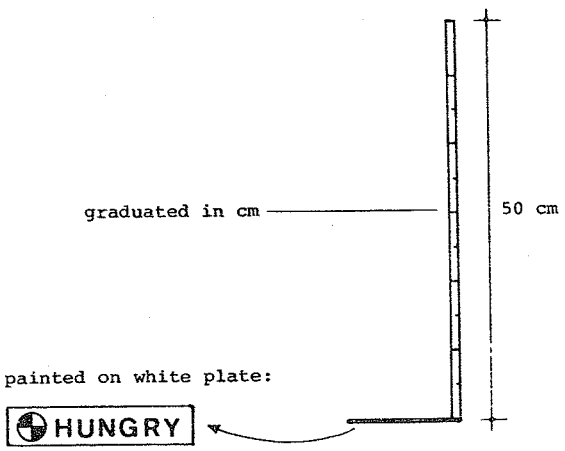

Fig. 10. Turbidistick used in *Artemia* culturing.

In order to maintain the food concentration in the culture medium as constant as possible, we have developed and tested various techniques for automatic food distribution. An example of a cheap and reliable system which we now are using since several years on varous types of raceways is represented schematically in Fig. 11. This system works as follows : in order to prevent particle sedimentation in the food stock, the suspension of rice bran in saturated brine (up to 150 g rice bran/l brine) is gently aerated in a conically shaped container. The latter can eventually be assembled from polyethylene sheet using electrical sealing equipment. Via a

siphon curved at the end (as shown in Fig. 11) or preferably via a water tight connection in the bottom part of the container (using a PVC manifold with screw fitting and rubber rings), the food suspension flows to a T-piece, one end of which is connected to an air inlet, the other one to the food distribution tube extending above the water level in the food reservoir. Every preset time interval during another preset time period, (both to be adjusted in function of the food requirements determined through manual turbidity readings), an electric clock activates the air pump which triggers food distribution to the raceway.

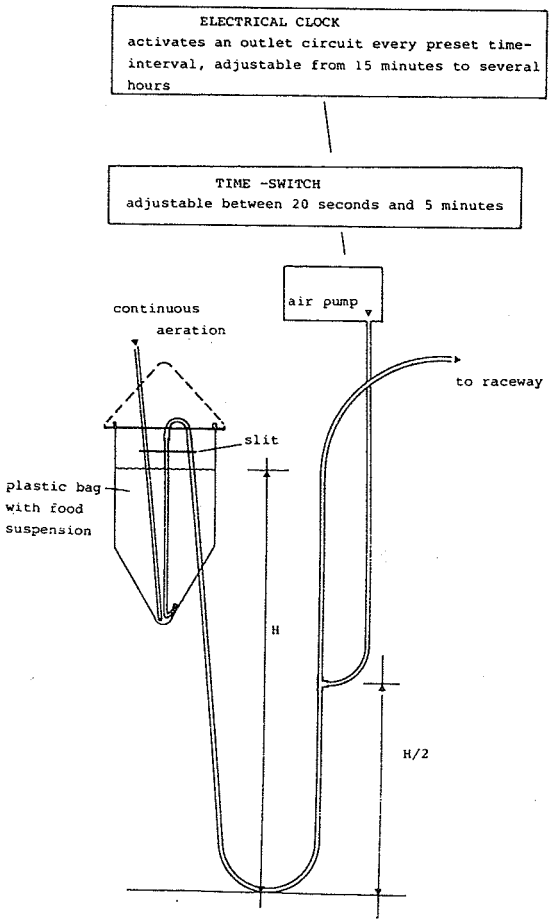

FIG. 11. Schematic diagram of air-lift operated food distribution system.

Full automatic food distribution can be achieved with an electronic turbidimeter. In the self-cleaning system described by Versichele *et al.* (1979), a glass syringue is filled every half an hour with culture medium. When the piston reaches its highest position the optical density of the medium is measured by a photo-electric transistor. The food distribution system is

triggered when the preset critical optical density is surpassed. A few seconds later the piston returns to its original position cleaning at the same time the inside part of the syringue.

Automatic systems for the primary treatment of the culture medium

To culture *Artemia* in high densities (3 000/l) in batch conditions, accumulation of faeces in the culturing tank should be minimized since it seriously interferes with growth and survival of the population. Decomposition of faecal material and uneaten food indeed affects the water quality. Furthermore faecal pellets and exuviae physically hamper the uptake of food particles. Using any of the culturing technologies described in this paper implies removal of the faeces from the second week on.

To separate the waste from the culturing medium, we have been using two different systems into which the faecal material is concentrated by sedimentation. We recently started experimenting with a third technique, namely a new type of filter screen capable to remove particulate matter from the culture medium.

THE PLATE SEPARATOR (Fig. 12)

This apparatus is a modified version of the plate separator developed by Mock *et al.* (1977) for primary treatment of solid waste produced by *Penaeus* postlarvae. The separator consists of a rectangular tank subdivided in a small inflow and a large settling compartment interconnected by an opening at the sloped bottom part of the tank. In the settling compartment several plates with a rough surface are mounted in an inclined position oriented in the direction of the water flow through the separator tank. A small PVC tube with a longitudinal slit is fixed to the bottom of the tank in its deepest part, and is connected to a removable siphon-tube outside the separator.

The working principle of the faeces separator which is installed next to the raceway is as follows : an AWL surrounded at the inlet by a 0.5-1.0 mm screen-cylinder [and eventually equipped with an aeration collar at its bottom part to prevent clogging (Tobias *et al.*, 1979)] is placed inside the raceway culture medium. This AWL continuously pumps culture medium loaded with particulate matter (*e.g.* faecal pellets, food particles and eventually newborn nauplii) into the inflow compartment of the separator. Through the opening at the bottom of the separator, the suspension flows in the settling compartment where the inert particulate material accumulates on the bottom and on the plates ; the nauplii swim to the surface and flow back in the raceway via the plate separator outflow where they can eventually be harvested in a 200 μm filterbag.

In order to promote sedimentation of the waste and to prevent clogging of the interspace between the plates, the latter are installed at minimum distances of 2 cm from each other at an inclination of 30 to 45°. Sedimentation of the waste is optimized by adjusting the air-water-lift rate since the latter determines the retention time of the suspension in the separator tank. We have experienced that a 20 to 30 min retention time permits a good separation of most of the waste particles while on the other hand small and light food particles do not get a chance to sedimentate and are drained back into the culture medium.

The characteristics of a plate separator currently used to treat a 2 m^3 raceway are summarized in Table II.

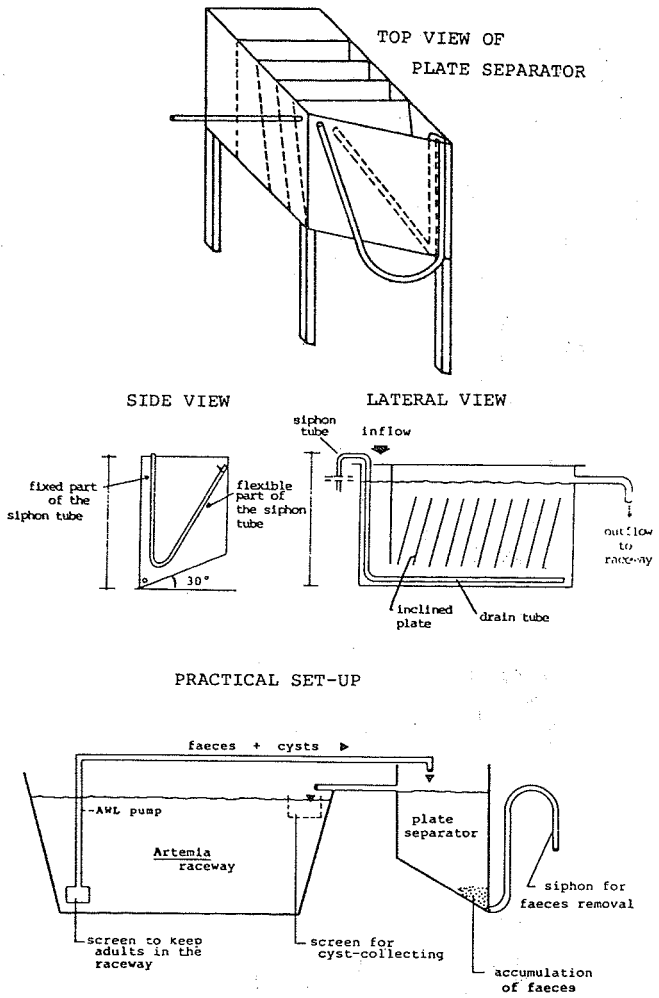

FIG. 12. Different views of plate separator.

TABLE II

Characteristics of plate separator used to treat a 2 m³ *Artemia* raceway

Dimensions : lenght	60 cm
width	40 cm
depth	50-80 cm
Number of plates	11
Inclination of plates	30-45°
Inclination of bottom part	30-40°
AWL diameter	2.5 cm
AWL pumping rate	3-4 l/min
Filter cylinder : height	50 cm
diameter	10 cm
Faeces drain : diameter	2 cm
Retention time	30-40 min

Since anaerobic decomposition of the accumulated waste materials can affect the water quality of the culture medium, the settled particles have to be drained off once every 2nd day by disconnecting the siphon and lowering its outflow. It should be noted that after a few days of operation faeces also accumulate on the bottom of the filter cylinder surrounding the AWL inlet.

Although plate separators are very efficient to remove faeces, a major drawback, however, is their large size (1/10th of the raceway volume) and the resulting problems in the prevention of heat loss.

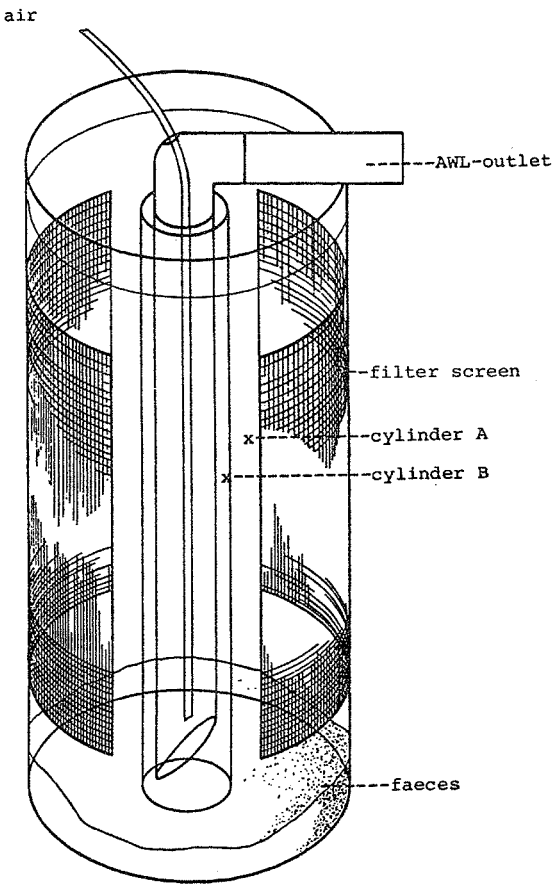

FIG. 13. Schematic diagram of a tube separator.

THE TUBE SEPARATOR (Fig. 13)

Although less efficient than a plate separator we have experienced that a tube separator can often be used as a valuable alternative for waste removal, especially since it can be installed inside the culture tank. This separator consists of a PVC cylinder A, with closed bottom and with very large lateral openings (leaving a type of frame structure) provided with a tightly

fitting filter screen (0.5-1 mm mesh). Clogging of the filter cylinder is prevented by the cleaning effect of an aeration collar (Tobias *et al.*, 1979) fixed at the bottom part of the cylinder.

An AWL tube is mounted inside cylinder A, within tube B. The bottom of the latter cylinder (the diameter of which is slightly wider than the AWL) is also closed.

Dimensioning has to be so that cylinder A of the tube separator, which is placed vertically on the bottom of the culturing tank, extends slightly above the water surface and cylinder B under the water surface (in order to permit the pumping of water back into the culture via the AWL).

The separator works as follows : under the influence of the AWL pumping, culture medium, waste material, food particles and eventually newborn nauplii are sucked into filter cylinder A, while the adults and pre-adults which cannot pass the screen, are retained in the raceway. By adjusting the flowrate of the AWL the waste and the nauplii can be separated, *i.e.* the faecal pellets sink while the nauplii tend to swim to the surface and are returned via the AWL to the raceway. Since the retention time of culture medium within the tube separator is short, food particles do not settle out but are also drained back into the culturing tank. Nauplii can eventually be harvested by placing a 200 μm filter bag underneath the AWL-outlet. Once a day, the waste accumulated on the bottom of cylinder A has to be siphoned off or be poured out.

The characteristics of a tube separator used for a 350 l raceway are summarized in Table III.

TABLE III

Characteristics of tube separator used to treat a 350 l *Artemia* raceway (all dimensions in cm)

Cylinder A	diameter	9.5
	height	45
Cylinder B	diameter	6
	height	40
AWL	diameter	3
Pumping rate (l/min)		2-3

THE CROSS FLOW SIEVE OR WELDED WEDGE WIRE SCREEN

This self-cleaning dewatering sieve is used in waste water treatment for the removal of solids from large volumes of waste water (Poels *et al.*, 1979). As schematically outlined in Fig. 14 it basically consists of a stainless steel welded wedge screen which is placed under a certain inclination and which is provided with slit openings of 150 μm.

Culture medium, screened for larvae and preadults by a filter system similar to that used in a plate separator, is continuously pumped into the head box and evenly distributed over the acceleration deck of the cross-flow-sieve-system. Under optimal conditions of orientation of the screen and speed of the suspension, the thin flowing layer of culture medium is sliced : *i.e.* according to the so-called "Coanda-effect" water and food particles tend to cling to the wall of the preceding bar, which results in their draining through the screen from where they flow back to the raceway culture, whereas oversized particles, *e.g.* faecal pellets, exuviae, *etc.* and

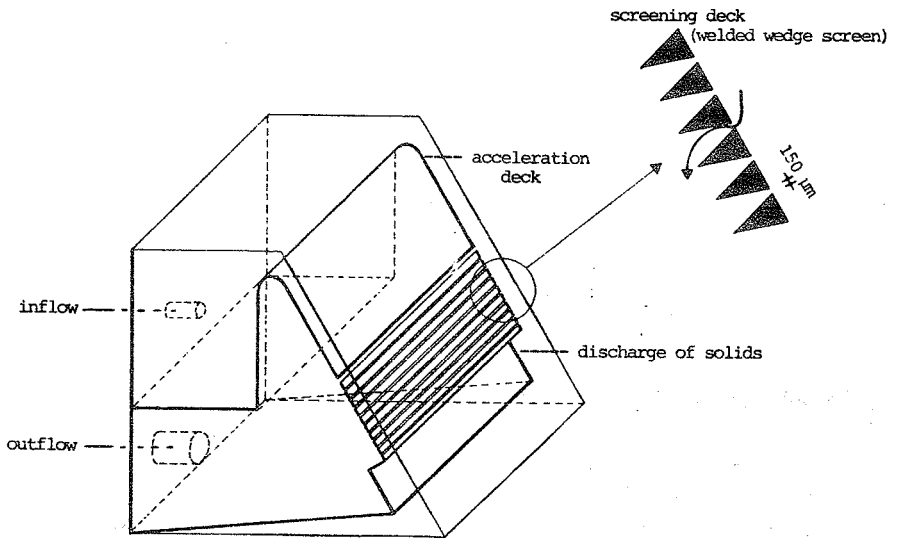

FIG. 14. Cross flow sieve system used for *Artemia* faeces removal.

eventually nauplii are discharged from the lower edge of the screening deck into a small separation tank installed just above the water surface of the raceway. In the latter tank particulate waste settles out (as a result of the long retention time due to the very low volume of water flowing in the separator tank) and the water is drained back into the raceway via the overflow. Nauplii, if present, are attracted by light to the overflow of the separator and also flow back in the culture tank.

Although application of cross flow sieves in *Artemia* culturing has to be studied further we can already point to a major advantage of the cross flow sieve over the other separation systems described : very large volumes of water can be treated on a small screen surface, concentrating the particulate waste into a wet paste. Working with a screen of 15 to 20 cm side, we obtained a satisfactory separation in a 2 m^3 raceway at a pumping rate of 15 to 20 l/min.

Culture procedure

a. natural or synthetic seawater : 30-50 ‰ salinity ; pH : 7.5-8.5
b. density of nauplii : 1 to 3/ml
c. water temperature : 25-30 °C
d. inoculation procedure :
   - incubation of decapsulated cysts for hatching (Bruggeman *et al.*, 1979, 1980 ; Sorgeloos, 1980) ;
   - harvest of instar I population preferably in the late afternoon (the exact timing to start the incubation is function of the water temperature and salinity and the hatching characteristics of the strain used) ;

- eventually counting by subsampling for determination of the exact number of larvae ;
- transfer of a predetermined number of nauplii in the raceway ;
- manual food distribution to a turbidity of 15 cm ;
- no food distribution overnight (the nauplii are first consuming their yolk reserves and there is nearly no food uptake during the first 12 hr) ;
- manual or preferably automatic food distribution from the next morning onwards.

e. food is distributed either manually a few times during the day or by preference automatically at preset time-intervals during the day and at night in order to keep the turbidity of the culture within the range of 15 to 20 cm ;

f. the daily food quantity has to be adjusted to the size of the larvae either by a more frequent food distribution and/or by increasing the quantity of food ;

g. from the second week onwards (when the animals reach a size over 4 mm) waste material should be removed at the aid of a separator, starting with a filter screen of 500 μm and replacing it progressively by screens of 750 and 1 000 μm ;

h. after one or more weeks the aeration lines may have to be checked and eventually cleaned to avoid blockage by salt deposition at the inner side of the airtube ;

i. important water quality parameters should be monitored regularly during the culturing period, *i.e.* dissolved oxygen, pH, and ammonia.

Artemia larvae are very resistant to low oxygen levels and still survive at 2 ppm O_2 ; Provasoli (1969) indicated that brine shrimp do not survive at pH values below 7.0. With regard to the ammonia concentration Hanaoka (1977) reported inhibition of food ingestion already at 2 ppm NH_4^+-N whereas we found that *Artemia* can tolerate levels up to 50 ppm NH_4^+-N. Since ammonia toxicity is greatly influenced by other abiotic parameters, especially pH (Kinne, 1976 ; Bower and Bidwell, 1978), no specific tolerance limit can be given for this important parameter.

A sound management and proper application of the culturing technology as described in this paper has, however, taught us that no specific problems are encountered with water quality for periods up to 6 weeks of batch culturing, without any renewal of the culturing medium.

Production results

The production figures which we obtained in routine batch culturing are summarized in Table IV.

TABLE IV

Production results obtained for various batch culturing tests

Tank volume (l)	Culturing period (days)	Wet weight harvest (g)
350	21	900
1 000	7	1 250
1 500	7	1 800
2 000	21	5 000
2 500	7	3 250
5 000	10	12 000

On the average 2.0 kg wet weight biomass can be produced at 25 °C in a 1 000 l raceway system within about 2 weeks batch culturing starting from approximately 10 g cysts.

Details on the biochemical composition (fatty acids and amino acids) of *Artemia* cultured on rice bran are reported by Dobbeleir *et al.* (1980), respectively Sorgeloos *et al.* (1980).

Conclusion

The present paper only aims at demonstrating the technical feasibility of high-density culturing of *Artemia* on a cheap diet. The results obtained are comparable with the literature data of Person-Le Ruyet (1976) who produced 1 kg of *Artemia* per week per cubic meter using a more complex culturing technology and a more expensive food (*Spirulina* powder) ; they are furthermore by far better than the figures reported by Jahnig (1977) who obtained 0.7 to 1.2 kg per month per cubic meter using polythylene tanks of 280 l content and whole-wheat flour as food. More detailed studies have to be performed to further increase the present production results and to determine the exact cost-benefit of this methodology at a larger scale.

The potential applications of batch culturing in raceways are numerous :

a. The production of bigger larvae, preadults and/or adults as live, frozen, or dried food for aquaculture hatcheries as well as for the petshop market. In comparison to the current technology where only freshly hatched nauplii are used to feed larval stages of crustaceans and fish, rearing of *Artemia* can lead to an important saving of the quantity of cysts needed ; it is known furthermore that in many cases older *Artemias* are more nutritious than freshly-hatched nauplii (Aquacop, 1977 ; Purdom and Preston, 1977) ;
b. The continuous production of offspring by the adult *Artemia*, to be used either as a direct food in the aquaculture hatcheries or for further ongrowth as under (a) by batch culturing for some time ; this application could again result in an important saving of the quantity of cysts needed and should allow *e.g.* to use selected strains with good nutritional characteristics (e.g. parthenogenetic strains) of which only limited quantities of cysts are available ;
c. the conversion of particulate waste products into highly nutritive animal protein which can be valorized either as an ingredient in human food or as a protein-ingredient of feeds for terrestrial and/or aquatic organisms (Sorgeloos, 1980).

In this regard experiments are in progress at or are coordinated by the Artemia Reference Center on the following topics :

- food conversion efficiencies with a micronized rice bran diet in function of larval density, water temperature and density of food particles ;
- cost-benefit analyses of batch and flow-through culturing of *Artemia* on micronized rice bran in AWL-raceways of varying size ;
- culture tests with various other particulate waste-products (technical feasibility studies) ;
- nutritional value analyses of *Artemia* grown on various diets (including diet combinations and/or alterations).

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